MAKING DIAMONDS BY HEAT AND PRESSURE

By A. Frederick Collins.

HARD upon the announcement from Paris of the marvellous qualities of radium and its value for testing the genuineness of diamonds comes a cablegram stating that making real diamonds artificially by electricity is a success. These manufactured stones are not base imitations, but genuine diamonds made under the same conditions that nature employs, that is, heat and pressure, and these absolutely essential factors are obtained by means of the electric furnace. It is also true that they are not large diamonds.

Professor Henri Moisson, of the University of Paris, famous for his researches in electro-chemistry, has at last been rewarded in his attempts to reproduce the crystallized gem of nature so highly valued by connoisseurs and so much sought after by society.

The manufacture of diamonds by the electric furnace process is directly due to Lavoissier, who showed conclusively that the diamond was merely crystallized carbon, just as glass is crystallized sand. When this deduction had been made by Lavoissier and had been proven by a complete physical demonstration, electro chemists set to work in earnest to devise the same conditions under which the gems were produced by nature.

It is well known that the diamond is but another form of carbon, and as it is easy to obtain carbon, since it occurs in combination in nearly everything in nature, including vegetable and animal life and their fossil remains, it would seem not unreasonable to find a method to obtain the diamond artificially.

When carbon is found uncombined with other substances it occurs in three very different forms, namely (1) as the diamond, (2) as graphite or plumbago and (3) as amorphous carbon. When the diamond is found in the celebrated beds of Borneo, Sumatra, Brazil or the Cape of Good Hope it is covered with an opaque layer before its beautiful properties appear.

Concerning Graphite.

Graphite is found in nature in large quantities, and it may be prepared artificially by dissolving charcoal in melted iron, and when this mixture has cooled graphite will be deposited; all forms of carbon which are neither diamond nor graphite are called amorphous carbon, meaning simply that they are not crystallized. Amorphous carbon may be obtained easily by burning wood in a kiln, the resultant product being charcoal, or coal may be fused in a retort, the product being coke; if coke is powdered and mixed with molasses and baked in a furnace, the form of carbon used for arc lights results; the temperature required for obtaining this kind of carbon is very low—a degree ranging from 50 to 200 Centigrade being quite sufficient.

A curious anomaly relating to graphite is that it is one of the best lubricators known for machine bearings, whereas carbon, its predecessor, and diamond, its successor, are both so hard and sharp either would cut a steel shaft to pieces in a few seconds. In fact, graphite is so soft that it will leave a mark on paper and is used in the manufacture of lead pencils.

The degree of heat sufficient to produce arc light carbons, or graphite, is not nearly great enough for the formation of crystals. It requires a temperature of approximately 6,000 degrees to produce very small artificial diamonds, and when nature made those in her famous diamond beds a heat of probably not less than 10,000 degrees was utilized in the process.

The purpose, then, of the electric furnace in the electro-chemical production of diamonds is to obtain as high a degree of temperature as possible. The electric furnace is an exceedingly simple and at once a clever device for producing high temperatures. In its simplest form it consists merely of an electric arc light joined between two carbons of large diameter, the heat of which is concentrated in a little crucible of graphite.

Of course the light of the arc has nothing to do with the chemical processes evolved in the crucible, whether it is employed in the manufacture of aluminum-silexicon or crystallized carbon, but it is the terrific heat emanating from the arc that consummates the operation. The electric furnace in which Moisson made the artificial diamonds is shown in the engravings, and the diagram gives an excellent idea of its interior construction.

It consists of an iron casing having a lower block of carbonate of lime constituting the body of the furnace. The reason carbonate of lime is used is that it is not apt to split under the intense heat and because it can be obtained in solid blocks of large size.

Crucibles of Carbon.

A cavity is formed in the lower block for the crucible, which is made of moulded carbon. In the earlier experiments of Moisson retort carbon was used, but it was found that the intense heat converted the carbon into graphite, causing it to swell out of shape. The crucibles are about three inches high and four inches in diameter. When the crucible is set into position in the hollow block of lime, the carbons, placed horizontally, are directed through the furnace over the mouth of the crucible. These carbons are two inches in diameter and are capable of carrying a current of 1,000 amperes at 500 volts pressure.

By multiplying the amperes by the volts we get the total amount of electrical energy in watts. Now, there are 547 watts in a horse power, and a simple calculation shows that a current equal to sixty-seven horse power is consumed in generating heat sufficient for the making of a diamond.

The conversion of this amount of electricity into heat in the small space of the crucible will raise the temperature of its interior cavity so that it will melt fifteen grains avoirdupois of tungsten, a most refractory metal, in five minutes.

It is evident that such high temperatures cannot be measured by any ordinary thermometer. Instead a special indicator of temperature for measuring the whole range of electric furnaces has been devised. This type of temperature indicator is called a "pyrometer" and is an electric device, arranged so that two dissimilar metals form a circuit, and by treating these metals at the juncture a current of electricity is produced. The electric couple in the pyrometer is made of platinum and rhodium encased in a long tube of porcelain. The electric current generated is measured by a galvanometer.

Such is the furnace devised by Moisson and such is the means for determining the degree of heat. Before attempting to duplicate nature in the production of the diamond the experimentalist must needs know something of her secrets as revealed by chemical analysis, for analysis should come before synthesis.

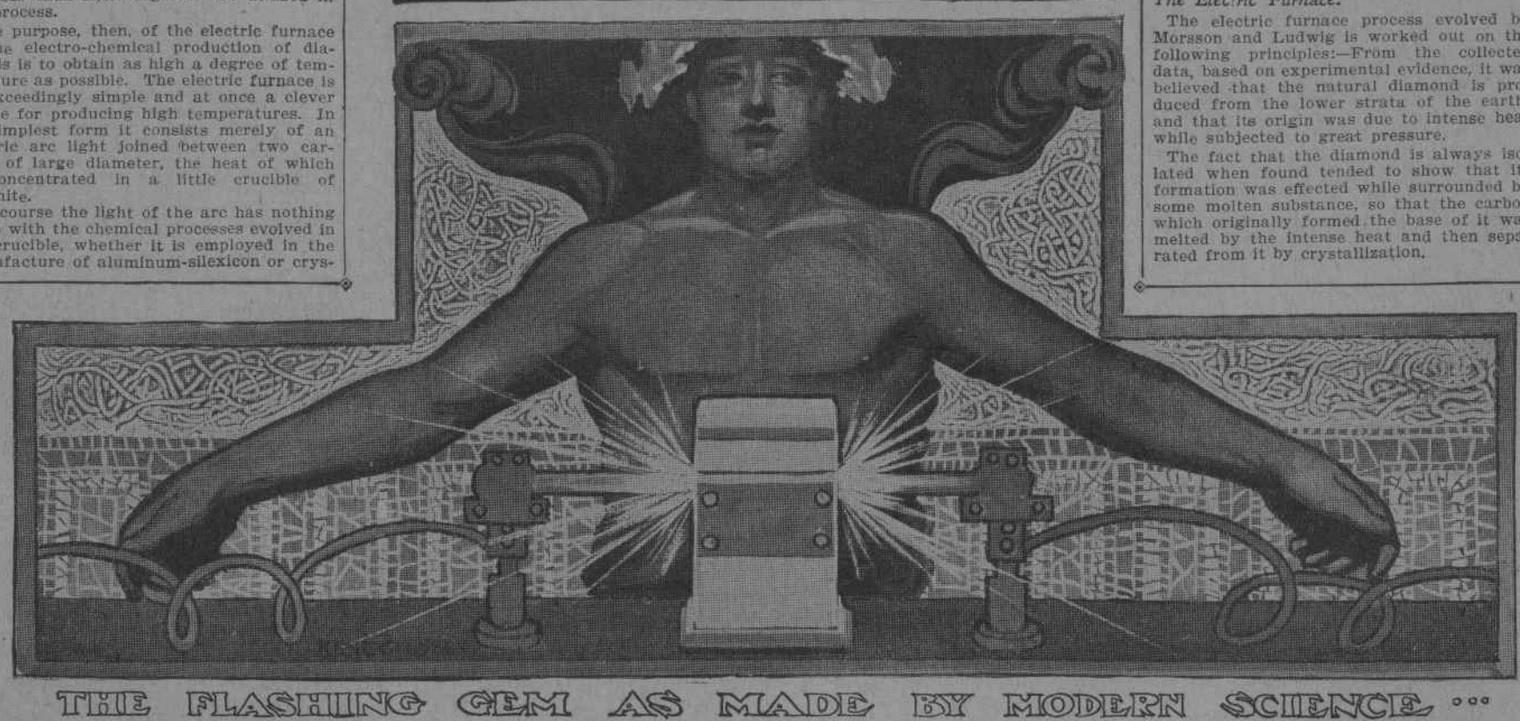
A genuine diamond possesses three properties, and any substance to be classed as a diamond must fulfil these requirements absolutely and unequivocally. For instance, a diamond is the hardest substance known and has a density of three and five-tenths; the second test for the diamond is that a real one will burn up in oxygen when heated to 700 degrees, and a diamond weighing 15 grains will yield approximately 23 grains of carbon dioxide, a compound of carbon and oxygen and commonly called carbonic acid gas.

There are substances which fulfil two of the three conditions, as boride of carbon, since this will burn in oxygen and give off carbonic acid gas, and there are several elements now manufactured in the electric furnace that are nearly as hard as the diamond—one of these substances is corborundum, which will scratch a ruby—and some substances have a density equal to the diamond, such as titanium, but none of these have the properties in triplicate that are required to stand the tests of the diamond. But the resultant crystallized mass found in the crucible of the electric furnace after the process for making diamonds is completed fulfil all the above conditions imposed, and the product must therefore be genuine diamonds.

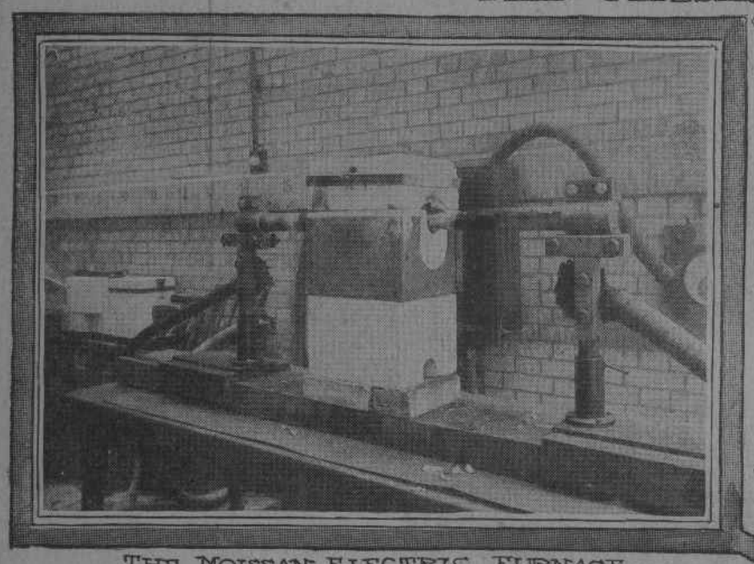
The Electric Furnace.

The electric furnace process evolved by Morsson and Ludwig is worked out on the following principles:—From the collected data, based on experimental evidence, it was believed that the natural diamond is produced from the lower strata of the earth, and that its origin was due to intense heat while subjected to great pressure.

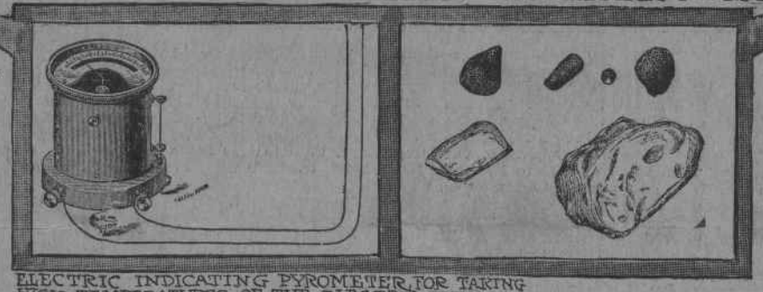
The fact that the diamond is always isolated when found tended to show that its formation was effected while surrounded by some molten substance, so that the carbon which originally formed the base of it was melted by the intense heat and then separated from it by crystallization.



THE FLASHING GEM AS MADE BY MODERN SCIENCE ...



THE MOISSAN ELECTRIC FURNACE.



CARBON CONTAINING DIAMONDS MADE BY THE ELECTRIC FURNACE.

ELECTRIC INDICATING PYROMETER FOR TAKING HIGH TEMPERATURES OF THE ELECTRIC FURNACE.

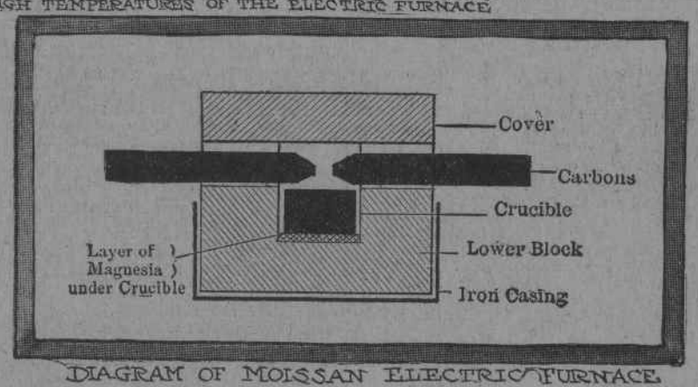
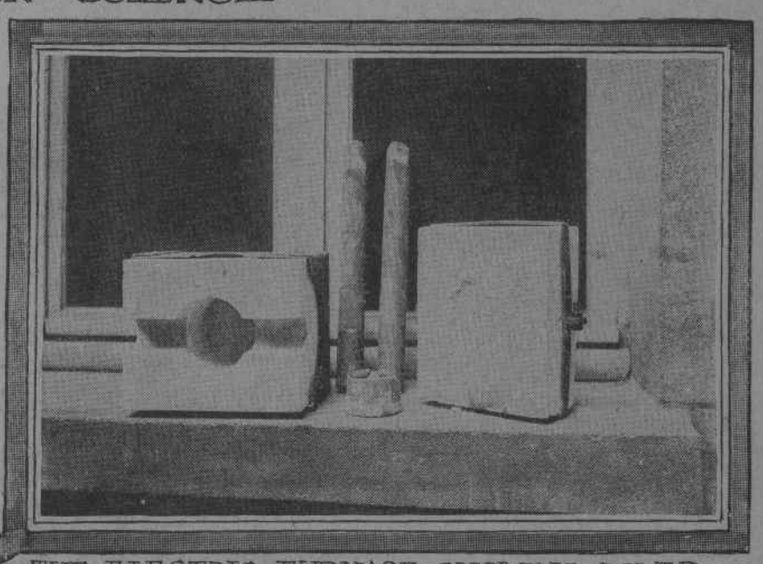


DIAGRAM OF MOISSAN ELECTRIC FURNACE.



THE ELECTRIC FURNACE, SHOWING LOWER BLOCK HOLLOWED OUT, AND ITS IRON CASING

Resorting again to experiment, it was ascertained that under these conditions of heat and pressure the carbon was dissolved most easily and perfectly when placed or immersed in melted metals, but that iron served the purpose best.

To perform the experiment of making real diamonds by artificial means place in the crucible about a quarter of a pound of Swedish iron, together with the powdered carbon, to be transformed by crystallization into the diamond. This mixture is then covered carefully with powdered charcoal.

The crucible is set in the furnace, the current is turned on and the arc is formed. In six minutes the highest possible heat is developed, and the part high temperature plays in the art of diamond making is realized. It only remains now to subject the carbon to great pressure. To obtain the requisite high pressure after the iron and carbon have been melted, or in fusion, as the physicist would say, the maximum temperature having been reached, the cover of the furnace is removed, and the crucible, with its epoch making contents, is quickly grasped by a pair of tongs and plunged into cold water. The result is that the iron, heated to a point of incandescence, contracts instantly and with such force that the particles of carbon held in suspension in its liquid mass are increased in density from 2 to 3.5. Careful examination reveals brilliant minute carbon crystals, possessing the hardness, specific gravity and refraction of the diamond. Spherical masses the size of peas were obtained by Ludwig, who intends to develop the process for the commercial manufacture of the gems.

The process of cooling the crucible, with its precious ingot, is not unattended with danger. Every one is acquainted with the effect caused by cooling a bit of hot metal in water, and thus volatilizing a little portion of the latter; it is easy to imagine what a melted mass of iron heated to a temperature of 3,000 degrees would do when it came in sudden contact with cold water. By proceeding with due carefulness no accidents occurred.

Exploding Bismuth

While fused iron may be thus treated without any untoward results, bismuth heated to the same degree and then suddenly cooled explodes with great force.

The cooled mass of iron and carbon in which lie the concealed diamonds is next immersed in a vessel of hydrochloric acid, which dissolves all the iron, leaving only the carbon elements previously contained in it. Mixed with the minute crystallized carbon are the other and more common kinds, one in the form of graphite and the other appearing as a dark colored carbon in the form of strips.

It is a strangely curious fact that in a meteorite found in the Diablo Cañon there are embedded the same kind of carbon strips as those produced in the electric furnace. To separate the diamond crystals from the common form of carbon the residue containing them is placed in aqua regia, made by mixing together concentrated nitric and hydrochloric acid, which dissolves more of the carbon away; the remaining residue is again treated by immersing it in sulphuric acid heated to 200 degrees and forcing nitrate of potash into the seething liquid, when all the common carbon particles are destroyed, leaving only the denser carbon fragments.

To obtain the pure crystals the last analysis is performed by placing the remaining particles in bromoform, a liquid having a density of 2.9, so that those pieces of carbon having the same density will float on the surface of the fluid and those having a higher specific gravity, such as the crystals, will be precipitated or fall to the bottom.

Finally the precipitate is placed in a vessel containing iodide of methylene, which is a very dense liquid. Again some of the carbon is deposited and some floats on its surface. These are the transparent diamonds, some having smooth surfaces and some having curved lines, and are of the same general appearance as the natural diamond in the rough.

Some of the diamonds made were covered with black carbon, which taxed the maker to dissolve it. One of the diamonds had a yellow color. A striking characteristic of one of the artificially produced diamonds was exhibited when it split into two different pieces after a period of three months, exactly like some diamonds procured from the Cape mines. This coincidence was due to the fact that in both cases the pressure at the time of formation was very irregular.

When a ray of light is projected into the stones they are luminous and under the action of radium they phosphoresce beautifully.

ACCOUNTED FOR.

"I wonde why Deacon Jones always asks to have long metre hymns sung?"

"I can't say, unless it's because he is connected with a gas company."

With the Cooper Hewitt Light the Artistic Photographer Is Independent of the Sun.

Mr. Hewitt's Invention Has Nothing of the Hard, "Stary" Effet of Flashlight.

Soft, Artistic Portraiture Can Be Made at Any Hour, in Any Weather.

A NEW light for exposing plates is the latest improvement in modern photography. Ever since the introduction of the dry plate, twenty years ago, the tendency of all effort to improve the art of picture making has been along the line of freeing the camera from the sun. In the old days when the sun refused to shine the photographer grew grave and, with tears in his eyes, turned much ready money away from his door, bidding it return when the sun should shine again.

The lay mind, through long training, believes thoroughly to-day that if it is raining, if it is overcast, it "is not a good day for pictures." When one thought of photography one thought of the sun, upon whose smiling face results depended. But such strides have been made in the art that the sun has almost ceased to exist for the camera.

Plates have been rendered so quick that an exposure of one one-hundredth part of a second is an everyday occurrence under a cloudy sky, while a thousandth part of a second is not impossible in the strong sunlight, and results can be obtained even at night by time exposure.

And there is practically no limit to what a photographer can do at night. The flashlight lamp illuminates the darkest halls, and since the invention of the quick printing paper, which, like a sensitized plate spread out on paper, requires but an instant's exposure to daylight, electric light or gaslight, a picture can be made at midnight and be on its way through the mails to its prospective owner before the sun is up next day. It is no exaggeration to say that the sun never shines on some pictures.

New Artistic Light.

But with all the improvements in light and material there had never been found a light which could be used for artistic lighting. The hard, "stary" effect of the flashlight is apparent to every one and the exposures made under electric lights are lacking in softness and modelling. The new light has none of these defects and will enable the artistic portrait photographer to work under all conditions of weather. It is the invention of Mr. Cooper Hewitt, son of the late Abram S. Hewitt.

It is really an electric light working through the fusing agency of mercury—a form of Crookes tube. Imagine a vacuum tube about one and one-half inches in diameter and four feet long standing on end and surmounted by a glass ball. Inside, at the bottom, is about an inch of mercury. Wires extend from it at the top and bottom. When the current is turned on immediately there appears in the tube a blue-white light. It spreads to the top of the tube, carrying some of the mercury with it in the form of a vapor. When it reaches the top of the glass the cooling influence of the ball comes into play and the vapor is converted again into mercury and falls down to the bottom of the tank, to repeat the action as long as the light is being used. The light itself which glows from the glass tube is rich in purple purity. To the eye it does not seem so bright. One can look at it steadily without experiencing any uncomfortable results.

The first man to use the new lamp is Pirie MacDonald, who makes a specialty of photographing men. He uses three of the tubes in what he calls his lamp. Unlike most photographers, he has no "top light" in his studio, securing his light from two large windows placed side by side. In the jamb separating these two windows is his lamp. The three tubes of light cost about $300. It takes 114 volts to run them, backed by a power equal to 2.8 amperes. He estimates the combined power of light at 750 candles.

"I believe I am the first photographer to use this lamp," said Mr. MacDonald, "and although I have had it installed only a few weeks I would not now be without it, because I have learned to depend upon it. You see, my difficulty has always been the question of light. I use very little light—only what you see coming through these two windows. A bright, glaring light, as you know, does not give any delicate modelling on faces, and that tone quality is what I am after. My best light here is about eleven o'clock. After that the smoke of the city closes in and it is all over. Unfortunately I work with the men, who cannot all happen in here at eleven o'clock. Even if they did, I could not handle more than one of them in the hour of good light. They like to get here about four o'clock, and then I have all kinds of difficulty in getting the light I want, and my lengths of exposure stretch out to eight and ten seconds, when it ought to be two and four.

Turns Back the Hours

"I needed something to help out my daylight, and I have found it in the Cooper-Hewitt lamp. At eleven o'clock I need no extra light. At two o'clock I turn on one tube and bring the quality of my light back to eleven o'clock. At four o'clock I turn on another tube and am again back to eleven o'clock, and at six o'clock I use the third tube and my light all night is equal to eleven o'clock A. M. light.

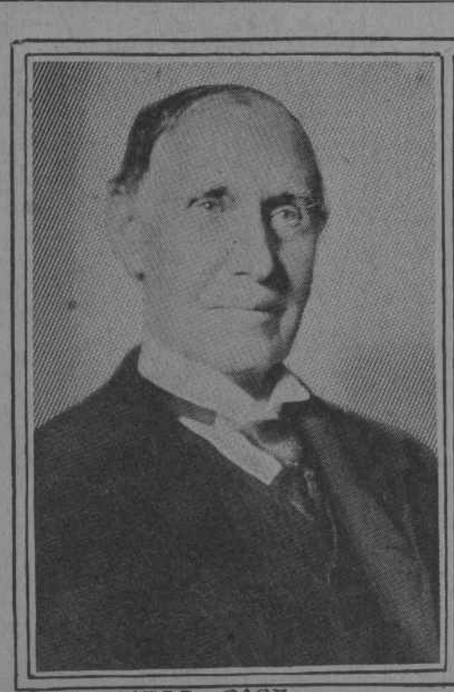
"With it I have to expose only the short time that I desire and by turning it off and on can control the amount of light with the same accuracy as I may my chemicals used later in developing my plates. For artistic portrait work, it is all that I can desire; it is ideal. It is so soft that it does not affect the expression of the face and yet so powerful actually that it is equal to daylight.

"I am enthusiastic about it and believe that nothing which has been discovered since the advent of the dry plate twenty-five years ago will so revolutionize photography, especially portrait photography, as will this light. It is an epoch maker.

"The ordinary electric light, incandescent or arc, is apt to be unstable, and it is 'hard.' The flash light is too gross to be considered. The field of this new light is broad. It can be used to illuminate theatres because the tubes can be protected for transportation by being placed in boxes, and all you have to do is to attach the electric wires to have your lamps working.

"We have sufficient light in the flash lamp for all practical purposes in theatrical work, but heretofore we have not had a single light which would aid the artistic photograph. No one knows exactly what the exact property of the light is. I know that it has no red rays in it and that it reduces the image on the ground glass to a black and white, so that I can form beforehand an accurate judgment of the resultant monochrome. As the light is constant in quality and quantity it is a simple matter to standardize the exposure and to control that most difficult thing called 'texture.'

"In portraiture texture is as individual as form, and until now the most expert photographers have been able only to suggest variety in complexional texture because of the changing light. If one uses the lamp alone without daylight there is possible the steady lighting of Rembrant or the soft, mellow handling of Reynolds without destroying the characteristic pose, because the light and not the sitter is moved."



MR. RUSSELL SAGE, PHOTOGRAPHED BY THE COOPER-HEWITT LIGHT
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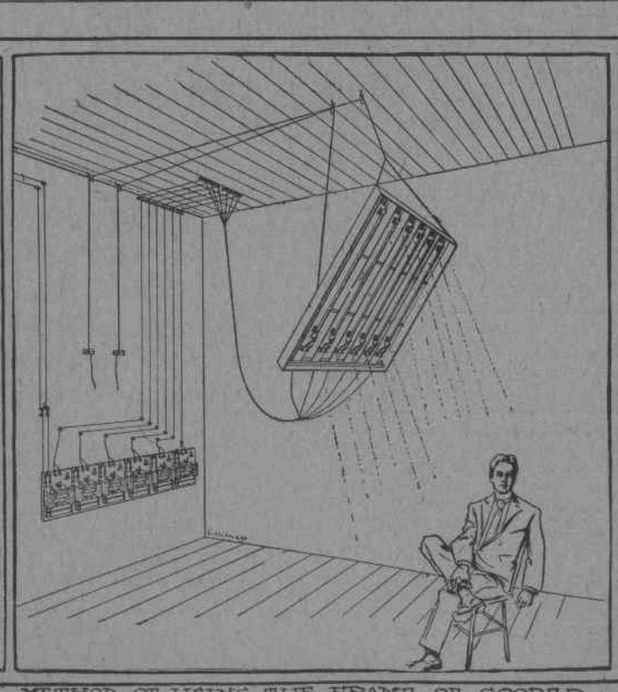
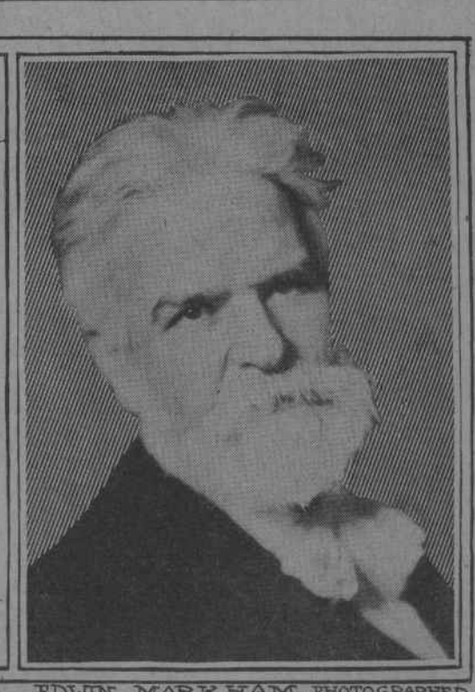


METHOD OF USING THE FRAME OF COOPER-HEWITT LIGHT TUBES IN PHOTOGRAPHY.



EDWIN MARKHAM, PHOTOGRAPHED BY THE COOPER-HEWITT LIGHT
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ONE OF EACH KIND.

At times fools rush in where angels won't go—
(Don't the poet say something like this?)—
But when a man rushes to back a poor show
He is both fool and "angel," I wis'.

—N. M. L.